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REPORT OF THE ARMY SCIENTIFIC ADVISORY PANEL AD HOC GROUP ON FIRE SAFE FUELS

MARCH 1976

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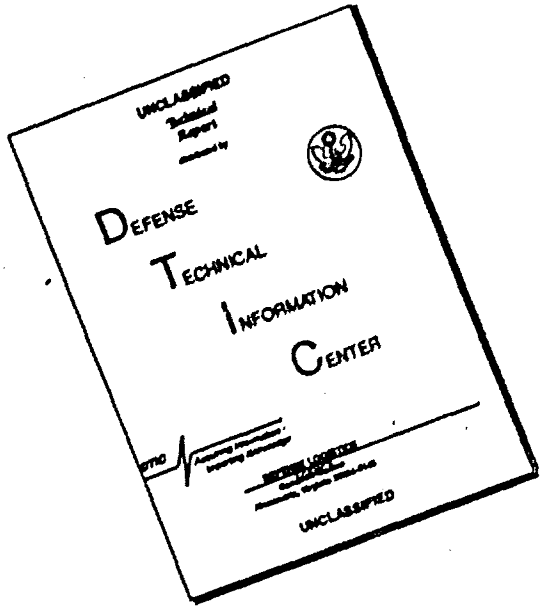

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REPORT OF THE

ARMY SCIENTIFIC ADVISORY PANEL

AD HOC GROUP

ON

FIRE SAFE FUELS

MARCH 1976

A

TERMS OF REFERENCE
ASAP AD HOC WORKING GROUP ON
FIRE SAFE FUELS

1. BACKGROUND.

The vulnerability of combat vehicles to catastrophic fuel fires is of continuing major concern to the U.S. Army. Research in the development of fire-safe fuels has been with us for a number of years with many varied approaches having been investigated. Although some approaches have experienced a degree of success, all have severe limitations. The benefits to be derived are apparent: enhanced survivability of personnel and equipment; potential savings in armor and related weight if shielding of fuel cells could be minimized; and increased opportunity to cannibalize on the battlefield.

At present in order to minimize the damage caused by fuel fires, fire extinguishment equipment is used as soon as possible after a fire has started. Armor plate is also employed to reduce penetration and so protect fuel from incendiary attack. In addition, reticulated foam fillers and floating foam surface layers have been used to reduce flame propagation inside fuel tanks, while methods of inerting ullage space or crew compartment by direct gas injection or fluid evaporation have also been tried. Finally, attempts have been made to modify the physical and/or chemical properties of fuels themselves.

Accordingly, there appears to exist a need for a structured program of basic research in the development of a fire-safe fuel for use in combat vehicles.

2. TERMS OF REFERENCE:

The Ad Hoc Group should produce guidance on this program by confronting the following issues:

a. What are the technological problems involved in developing a fire-safe fuel?

b. What potential solution approaches should be pursued in attempt to overcome these technological problems?

c. What are the applications for a fire-safe fuel within the Army, which are most desirable and cost effective?

d. What are the logistical ramifications of introducing an additional fuel into the inventory?

e. What environmental problems will be encountered, how best are they overcome?

f. What is the application of fire-safe fuel to other governmental agencies and civilian industry?

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GROUP REPORT

This report presents the findings and recommendations of the Army Scientific Advisory Panel Ad Hoc Group on Fire-Safe Fuels.

The group members are: John M. Deutch, Charles W. Ellis, Ralph E. Fadum, Herbert L. Ley, Jr., and Robert L. Hess, Chairman.

The terms of reference presented to the group were:

(a) What are the technological problems involved in developing a fire-safe fuel?

(b) What potential solution approaches should be pursued to attempt to overcome these technological problems?

(c) What are the applications for a fire-safe fuel within the Army, which are most desirable and cost effective?

(d) What are the logistical ramifications of introducing an additional fuel into the inventory?

(e) What environmental problems will be encountered, how best are they overcome?

(f) What is the application of fire-safe fuel to other governmental agencies and civilian industry?

The group has been provided with a well-balanced, comprehensive set of communications and technical papers dealing with its charge. These papers, assembled by Major Robert Stryjewski from the Office of the Deputy Chief of Staff for Research, Development and Acquisition, provided the group with a background on the Army's FSF program as well as the significant related research. The group recommends that this cohesive set of papers be periodically updated and preserved for future use by those concerned with the FSF program. The index of the file is annexed to this letter for reference.

The fire-safe-fuel program has dealt primarily with diesel fuels as opposed to aviation (turbine) fuels -- the Ad Hoc group agreed that diesel fuel, and in particular diesel fuel for armored vehicles (tanks and APC's), is the proper focus.

The fire danger in tanks originating with or being sustained by fluid from the hydraulic system was discussed and the availability of materials

and design (including retro design) capability seemed adequate. The group did not pursue the topic of fire-safe hydraulic fluids further.

It was observed that the Army's Fire-Safe-Fuels program consists primarily of elements of laboratory and engine testing dealing with two classes of fuel additives (a) high molecular weight, anti-misting materials and (b) halogen containing hydrocarbons. The first type additive is designed to reduce the fine mist associated with impact dynamics of fluid surfaces thus reducing fire-ball and/or ignition potential of the fuel. The second type of additive is believed to inhibit ignition (or burning) over free surfaces of non-contained fuel.

The FSF program is managed by Mr. H.L. Ammlung of the U.S. Army Mobility Equipment Research and Development Center with major participation by Dr. James Dehn of the Ballistic Research Laboratory, Aberdeen Proving Ground and Dr. W.D. Weatherford, Jr. of the U.S. Army Fuels and Lubricants Research Laboratory. Other laboratories and individuals are involved but the group worked with these individuals and they appear to be those who have made the major contributions to date. Each of the gentlemen mentioned was most helpful to the group.

The attention of the group primarily was devoted to the role of halogenated hydrocarbons as additives to diesel fuel to render it fire-safe. The Army program has given priority to Halon 1011 manufactured by Dow Chemical Co., Midland, Michigan. Known commonly as BCM in the army documents, this material is reported to be 98% by weight CH BrCl, bromochloromethane. BCM is a highly volatile material compared with diesel fuel.

It is well known that the mechanism of combustion is extremely complex, especially for diesel fuels and accordingly it is not suprising that a complete and quantitative description of the effects of fuel additives is not available. However, the literature presented to the group and the discussion of Army FSF program representatives led the group to conclude that the fire inhibition mechanisms of Halons is not only poorly understood but virtually unknown. For example, the technical literature contains widely different hypothesis for the mechanism of fire suppression including (a) free radical trapping mechanism and (b) temperature lowering due to increased heat capacity.

The group observes that the goal of the FSF program is not impossible. But substantial progress toward this goal requires in-depth experimental and theoretical research because of the complex physics and chemistry of the combustion process. The research base of the FSF development program is presently insufficient to provide any assurance that an optimum fuel will be found or to assure that unpleasant problems will not emerge from an apparent solution.

The group inquired about the fuel fire risk for armored vehicles in combat. Information from BRL report 1777 on M48A3 tanks, advice from Ft. Knox and from General Dickinson placed the fire threat in perspective. Fuel fires appear to be related to an otherwise probably disabling armor piercing hit. The hit may directly involve the fuel system or the fuel may be subsequently involved in what might best be called an ammunition fire. Physical separation of fuel and crew is present to a higher degree in tanks than in APC's. Most importantly there is little evidence that explosive fuel fires were at all common. The group was led to believe that the ignition by incendiary rounds and by pyrophoric action involving fuel storage tank material was effective in the ullage space. Field experience indicates that in a fuel-initiated fire the crew has sufficient time for engine blower shutdown and fire extinguisher operation in a large fraction of cases. This action is reputed not to be very effective in extinguishing fires but probably adds valuable time for evacuation.

The group failed to find evidence of a concerted effort to study mechanical means of fuel system fire management for current (or future) vehicles. One member suggested consideration of replacement of the fuel tanks with nonpyrophoric material during power pack pulls. Other mechanical concepts were discussed to the point that the group could conclude that this route of improving the fire safety of armored vehicles is inadequately explored.

The group expected corrosion and material interaction problems from the outset. There was documentation of primitive corrosion testing program and the judgment was made that the corrosion/material interaction with engine components was not so great as to preclude meaningful testing of a 400-hour AVDS 1790 engine with BCM additive. The group was skeptical that an adequate effort had been made in this area. In particular, the group observed that one would expect free atoms of bromine and chlorine to exist and be significant in the corrosion process and that scavanging additives might be effective. The group expressed a view that corrosion and material compatibility problems could be severe and that insufficient theoretical or research effort was programmed in the FSF program.

Discussion of the use of diesel fuel as a coolant for the fuel injection system was introduced in connection with the degrading of anti-mist compounds. These compounds are based on extremely high molecular weight macromolecules. Some anti-mist compounds will pass thru filters and others will not. Some form true solutions and some do not. Degradation was surmised to be effected by the recirculation mentioned above. The group expressed concern with regard to the use of fuel as a coolant - not because of the potential anti-mist degrading alone, but because the recirculation raises average fuel temperatures throughout the vehicle presumably increasing the fire hazard. It should be noted that the Soviets do not recirculate fuel and therefore enjoy lower fuel temperatures.

The group recommends a systems study that would address the question of fire-increasing potential of such fuel recirculation systems.

The lack of knowledge as to the mechanism of anti-mist action, the lack of knowledge of the compound design and of mechanism of its degradation when viewed in terms of the empirical evidence of its usefulness as a FSF additive make it imperative that a thorough going basic research effort be undertaken to establish the fundamental principles of the concept.

The group returned to discussion on the absense of a significant body of mechanistic basic research. It is unrealistic to believe that the FSF program would succeed, either in the short or long run, on a trial and error basis. It did seem that the FSF goal was realizable but should be supported by serious, bench scale, thermodynamic, chemical kinetics research on the entire field of halons. The group recommended that two groups of researchers, in well equipped research laboratories outside of the Army facilities, be given significant multi-year support for this purpose.

The group was impressed with the potential widespread and significant use of a successful FSF program and recommended that the Army request ARPA to undertake a research program in FSF technology. One member of the group has contacted appropriate ARPA officials in order to stimulate interest in the FSF problem.

The use of the halons in internal combustion engines - particularly when so little is known of the combustion products gives rise to two very significant additional questions: (a) long-term atmospheric effects and (b) the possible chronic toxicity impact. Both areas are speculative and will require exact and detailed combustion products analysis as inputs. The group cautions that such analysis be based upon a complete input-output mass balance so that no surprises will result through discovering a new product a year from now. Atmospheric impact studies and chronic toxicity studies will each require multiple year programs to reach reliable conclusions.

The well known chronic toxicity problems related to bromine and chlorine suggest to the group that the FSF program should lean toward iodinated compounds as being safest with regard to humans. Further advise to this effect has been received from expert toxicologists. The iodinated compounds are also furtherest removed from the florinated compounds which include the freons, strongly suspected as contributing to an upper atmospheric problem. The group recommends that a combustion products, atmospheric effects, chronic toxicity program be developed. The Army should develop, in advance, a thoughtful rationale for the FSF program and be in a position to respond to inquiries about the toxicity and environmental effect of the compounds used.

Logistics problem were discussed briefly. It is understood that there is a quick-fix connotation to the current BCM, FSF program which would take

stock of the trade-offs between the potential battlefield advantage of the BCM field use. The group was not impressed with any overwhelming seriousness of field mixing of BCM directly into tanks or into last distribution point systems. To the extent that a BCM-FSF, or any other quick-fix FSF is developed for limited armored vehicle field use, the group is of the belief that the logistics problems are readily manageable. However, the DA headquarters staff should be aware that there is strong resistance in logistic and armor circles to introducing BCM into the field army. The field army perceives major logistical problems.

Overall, the group advises that long-term chemical kinetics, environmental impact, and chronic toxicity programs be undertaken. Additionally, more aggressive corrosion/material influence and physical fuels management for fire safety efforts are required. The direction of the program should be steered more toward (or to at least seriously include) the iodinated compounds despite their higher expense and probabiliby poorer effectiveness. ARPA and high technology research laboratories should be in an expanded and more basic research program on the mechanism and design of FSF substances.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The vulnerability of combat vehicles to catastrophic fuel fires is of continuing major concern to the US Army. An Army Scientific Advisory Panel Ad Hoc Group was organized to review the present Army Fire-Safe Fuel program and provide guidance for future research and development efforts in this area. The group advises long-term basic research, environmental impact and chronic toxicity programs be undertaken. Additionally, physical fuels management efforts, corrosion/material influence, and involvement of DARPA should be pursued. Extensive bibliography is included.